

2.4.3 DEEP BOREHOLE CATEGORY

Under this category of alternatives, surplus weapons-usable Pu would be emplaced into one or more deep boreholes drilled below the water table into ancient, geologically stable rock formations. The Pu disposal form is emplaced and sealed in the emplacement zone, typically 2-km (1.25-mi) long. The isolation zone, also typically about 2-km (1.25-mi) long extends from the top of the emplacement zone to the ground surface, and would be filled and sealed with appropriate materials. At emplacement depths, which would be several kilometers greater than those of mined geologic repositories, the groundwater is expected to be stagnant. Because the barrier to transport posed by the isolation zone and the siting of the facility at a carefully selected stable location with stagnant groundwater at depth, the Pu is expected to remain, for all practical purposes, permanently isolated from the biosphere.

This PEIS analyzes two alternatives for emplacing Pu into a deep borehole: direct disposition and immobilized disposition. These are discussed in Sections 2.4.3.1 and 2.4.3.2, respectively. Under both alternatives, emplacement in a deep borehole would provide a geologic barrier to proliferation that would be difficult, costly, and time-consuming to overcome for recovering the material. According to the NAS, Pu in deep boreholes would be inaccessible to potential proliferators, but would be accessible to the state in control of the deep borehole site. Since the deep borehole is accessible to the nation in control of the deep borehole site, redrilling the hole could technically be accomplished within a few months. However, such activity would be detected well before the Pu was retrieved. As a result, it is doubtful that potential proliferators could recover the Pu or the host nation could recover the Pu without being detected. Therefore, under both alternatives, the Pu would not need to be mixed with HLW or other highly radioactive material to increase proliferation resistance. Under the first alternative, surplus Pu would be encapsulated directly in suitable canisters and emplaced into the deep borehole. Under the second alternative, surplus Pu would be converted into a ceramic pellet immobilized form. The ceramic pellets would then be mixed with grout and an equal volume of Pu-free ceramic pellets and emplaced into the deep borehole without canisters. Under either alternative, the deep borehole would be sealed after completion of the emplacement.

The environmental impacts of emplacement in a deep borehole are evaluated at a generic site that would be characteristic of a deep borehole complex. The identification of a suitable location for a deep borehole requires detailed site-specific studies and is beyond the programmatic scope of the Storage and Disposition PEIS. [Text deleted.] In addition, the regulatory requirements that the deep borehole must satisfy for site characterization and licensing for long-term disposal would have to be developed by the appropriate regulatory bodies.

2.4.3.1 Direct Disposition Alternative

Under this alternative, surplus Pu would be removed from storage, processed as necessary through the pit disassembly/conversion facility and/or the Pu conversion facility, packaged, and placed into a deep borehole. The deep borehole would be sealed to isolate the Pu from the accessible environment. The Direct Disposition Alternative does not require direct handling of dispersable Pu at the deep borehole site. Long-term performance of the deep borehole would depend on the stability of the geologic system to ensure isolation of Pu until rendered stable. No specific deep borehole locations have been identified but a generic assessment of site availability has been performed and site selection criteria have been developed (LANL 1996m:7-8, 27-38). This study has shown that suitable sites can be found in many regions of the continental United States. All requirements shown in this section are in addition to those previously stated for the pit disassembly/conversion and Pu conversion facilities.

Facility Description. Under the Direct Disposition Alternative, a deep borehole complex would be sited and constructed to dispose of surplus Pu material (Pu in various forms). Pu from the pit disassembly/conversion and Pu conversion facilities would be packaged to preclude criticality as determined by deep borehole disposal requirements. Two 2.25-kg (5-lb) product cans, a total of 4.5 kg (10 lb) of Pu, could be appropriately spaced inside each PCV. The PCV would be placed inside a shipping container (like a 6M) and shipped by SST to the

deep borehole complex. The sealed PCVs would be removed from the shipping containers at the deep borehole complex and placed directly into metal emplacement canisters and sealed with kaolinite sealant, without any handling of dispersable Pu material. Emplacement canisters would be 0.4-m (16 in) in diameter, 6.1-m (20-ft) long, and contain 9 PCVs, which collectively contain 40.5 kg (89 lb) of Pu. Twenty-five emplacement canisters would be connected end-to-end in an emplacement string approximately 150-m (500-ft) long to facilitate faster canister insertion. A material flow diagram can be found in Figure 2.4.3.1-1.

The deep borehole subsurface facilities analyzed in this PEIS would consist of an array of four separate deep boreholes, with each deep borehole separated approximately 500 m (1,640 ft) from the nearest hole. Each deep borehole could be up to 4 km (2.5 mi) in depth. Figure 2.4.3.1-2 shows a typical deep borehole in which the upper 2 km (1.25 mi) or more of depth (the isolation zone) would pass completely through the water table and sedimentary and/or fractured crystalline rocks. The isolation portion of each borehole would be cased with steel pipe and filled and sealed with appropriate sealing materials to prevent influx and contamination of near surface waters. The lower 2 km (1.25 mi) would be drilled into crystalline basement rock that is isolated from the accessible environment. The emplacement zone of each borehole would contain 12 individual 150-m (500-ft) emplacement canister strings that would be grouted or cemented into place. Undercut seals would be installed between the canister strings in the emplacement zone for additional protection.

The deep borehole complex would occupy a land area of approximately 2,041 ha (5,043 acres), of which 57 ha (141 acres) would be occupied by the main facility and the assumed four-hole borehole array, with the remaining approximately 2,000 ha (4,940 acres) being buffer zone. Operations involving the Pu disposal form in the Surface Processing Facility are performed in an MAA that is hardened for security purposes. However, no direct contact with Pu is required. The MAA and facilities supporting MAA operations are located in a PA. The emplacement and borehole sealing facility to which the emplacement canisters are brought is also within a PA. Each PA is a secure, fenced area. The PA and operations involving any classified materials are contained within the LA. The PPA surrounds the LA and includes the buffer zone around the facility. The passenger vehicle parking and personnel services facilities are located outside the LA but within the PPA. A deep borehole facility site layout perspective is shown in Figure 2.4.3.1-3, and a list of deep borehole site buildings can be found in Appendix B.

The deep borehole complex would be designed to ensure that surface facilities could withstand earthquakes, high winds, or floods. The fire protection systems of the facility would be in accordance with DOE Orders and National Fire Protection Association Codes and Standards. The physical security, MC&A, IAEA safeguards, and physical security system facilities would be consistent with protecting Pu materials in the deep borehole complex surface facilities. In addition, the material would be emplaced to ensure post-emplacement downhole nuclear criticality safety.

The deep borehole complex would be a stand-alone site containing five types of facilities grouped by function. These five are described in the following:

Surface Processing Facilities. Surface processing facilities would receive the Pu metal and oxide disposal forms, provide lag storage of the received Pu materials, load emplacement canisters with the Pu metal and oxide disposal forms, and seal the canisters.

Drilling Facilities. Drilling rigs (either portable or constructed in place) would drill boreholes, seal natural and drilling-induced hydraulically conductive pathways in the host rock, install the casing in the isolation zone, and cement behind the casing to ensure a good hydraulic seal. Drilling facilities would mix various additives into the drilling mud and bring up brine from the bottom of the borehole as it is drilled. For this reason, each drilling facility would be provided with a wastewater treatment subsystem.

Emplacing-Borehole Sealing Facilities. One or more emplacing-borehole sealing facilities would emplace the Pu-bearing canisters, seal around the canister, and plug the upper 2-km (1.25-mi) isolation zone of the deep

borehole. Workers would assemble canister modules into canister strings for emplacement at this subfacility. Under normal conditions, the water pumped from the borehole during emplacement operations would not be contaminated with radioactivity, and the wastewater would be treated as in any drilling operation. However, the water must continually be tested for radioactive contamination, and if contaminated, the water would be redirected to the main facility process wastewater treatment system. A containment structure covers the borehole entrance and emplacing equipment to contain any Pu that could be released in the event of an accident or canister breakage during emplacement.

Waste Management Facility. A waste management facility would treat the process wastes, process wastewater, utility wastewater, and sanitary wastewater generated by borehole disposal operations.

Support and Balance-of-Plant Facilities. A support facility would consist of administration, plant operations, and BOP. The BOP facilities would include security, plant alarm, safety and decontamination systems, shipping and receiving, central warehouse, maintenance, and utilities to provide general operational support.

Facility Operations. The borehole facility could process and dispose of 5 t (5.5 tons) of Pu, in all forms, each year. Operations would be based on continuous operations 7 days a week, 24 hours a day, in two 12-hour shifts with three drilling crews. A surge capacity of 10 t/year (yr) (11 tons/yr) could be achieved by introducing a second 8-hr shift in the surface processing and emplacing-borehole sealing facilities and by adding a second drilling rig and extra crews, as needed, in the drilling facility. Utility consumptions, chemicals consumed, and the number of personnel required during operations are listed in Appendix C.

The raw water requirement for the deep borehole disposal facility would be approximately 166 million liters (l) yr (44 million gallons [gal]/yr), of which 91 million l/yr (24 million gal/yr) would be consumed by the main facility area and the remainder consumed by the drilling and emplacing-borehole sealing facilities in the borehole array area. A raw water subsystem could be provided from production wells, supply pumps, and transfer piping to the facility water subsystem. The annual water balance for the borehole facility is shown in Appendix D.

Construction. Additional land area requirements during construction would be approximately 6 ha (15 acres) for construction laydown, warehousing, and temporary parking. The construction of the borehole complex would require 3 years and have a peak annual employment of 870 construction workers. Materials and resources consumed and employment needs during construction are listed in Appendix C.

Construction of the deep borehole array requires drilling several boreholes up to 4-km (2.5-mi) deep into geologically stable rock formations. This would be accomplished using drilling techniques based on technology developed for and used extensively in the petroleum, mining, and scientific drilling industries, and for deep boreholes drilled in crystalline rocks for disposal of HLW. The drill system would include a derrick to lower and raise the drillstring and bit and to route the slurry and cuttings. A slurry of water, compressed air, and bentonite additives would be pumped into the borehole to bring up cuttings. The used slurry then would be sent to a holding area to allow cutting solids to settle. The slurry would be filtered to remove coarser particles before it is recycled. When drilling holes down, two pipes, one inside the other, would be used. The fresh mud slurry would flow in the area between pipes (the annulus), and the cuttings would flow to the surface through the center pipe.

Boreholes would be drilled with their diameter decreasing with depth in a stepwise fashion, as dictated by site drilling conditions. A metal casing, smaller in outside diameter than the hole, would be inserted, and a cement slurry would be pumped at high pressure into the annulus between the casing and rock or soil in the isolation zone. Casing is not used in the emplacement zone. At specific locations in the borehole, the hole would be widened (undercut) to a larger diameter to provide a seat for seals and plugs. These seals and plugs, required to prevent vertical migration of fluids, would be installed during canister emplacement to achieve borehole closure.

A 3-year construction schedule is assumed for the deep borehole facility. The estimated total quantity of generated solid and liquid wastes associated with construction of the deep borehole disposal facility is shown in Appendix E. The waste generation data are based on factors from historic data on construction area size and construction labor force. Solid wastes would be hauled offsite for disposal during the construction period.

Waste Management. Waste management for the deep borehole complex would handle the treatment of criteria air pollutants, toxic and hazardous air emissions, and other gases emitted during operation and construction. Facility waste management would also include handling and treatment operations for processing TRU, low-level, and mixed waste, as well as industrial waste in aqueous, organic liquid, or solid forms generated from the onsite deep borehole disposition operations or from other site activities. Waste management would be in accordance with DOE Order 5820.2A and RCRA. TRU waste generated from deep borehole operations would be treated and packaged for disposal to WIPP (should DOE decide to operate WIPP for TRU disposal) in accordance with WIPP WAC (WIPP-DOE-069) and in accordance with decisions to be made as a result of the *Waste Isolation Pilot Plant Disposal Phase Supplemental Environmental Impact Statement*. A waste management process flow diagram is shown in Appendix E.

Estimated annual quantities of air pollutant emissions due to operation of the deep borehole disposal facility are shown in Appendix F. These emissions would result from minor borehole gases and fuel and gas consumption necessary to drill and, later, close the deep boreholes. Chemical processes that may lead to the release of contamination over time are unlikely in the abbreviated times associated with the canister emplacement, backfill, and closing processes. More likely are releases resulting from mechanical accidents where the containment canisters are breached.

Transportation. Intrasite transport of radiological materials will be limited to Pu metal and oxide container transport. There is no handling or processing of Pu on the site under normal operations. Intersite transportation of Pu material coming into the deep borehole facility from offsite would be in SSTs.

2.4.3.2 Immobilized Disposition Alternative

The second disposition alternative based on the deep borehole concept would immobilize surplus Pu in a ceramic spherical pellet form. Under this alternative, the output material from the pit disassembly/conversion and Pu conversion facilities would be sent to a ceramic immobilization facility. The ceramic immobilization facility would receive Pu feed in both oxide and metal forms. The output from the ceramic immobilization facility would be 2.54-centimeter (cm) (1-inch [in]) diameter coated ceramic pellets containing 1 percent by weight Pu. The ceramic pellets of Pu would be shipped by SST to the deep borehole facility. At the deep borehole facility the Pu-loaded ceramic pellets would be mixed with an equal volume of Pu-free commercially produced ceramic pellets and kaolinite clay grout and the mix would be directly emplaced in the borehole without any canisters. The drilling operations at the borehole facility would be similar to those described in the previous section. The emplacement of ceramic pellet-grout mix would be done either by bucket delivery or by pneumatically pumping slugs of the ceramic pellet-grout mix down a drill pipe. The sealing of the boreholes to isolate the emplaced Pu from the accessible environment would be as described in the previous section. Although representative locations for the ceramic immobilization facility are analyzed, no specific deep borehole locations have been considered. All requirements shown in this section, both for the ceramic immobilization facility and the deep borehole, are additive and are in addition to those requirements previously described for the pit disassembly/conversion and the Pu conversion facilities.

Facility description and operations, construction, waste management, and transportation descriptions for the ceramic immobilization facility are in the next section. They are followed by facility description and operations, construction, waste management, and transportation descriptions for the deep borehole complex.

2.4.3.2.1 Ceramic Immobilization Facility—Immobilized Disposition Alternative

Facility Description. A ceramic immobilization facility site of 18 ha (45 acres) would be required. The ceramic immobilization facility site layout is shown in Figure 2.4.3.2.1–1. The facility would be centered around a Pu processing facility and would contain waste processing and support facilities. The list of facilities is found in Appendix B. Support processes required at the immobilization facility would include radioactive liquid waste treatment, process offgas treatment, and waste solidification. Scrap recovery and Pu recycle, MC&A, cold chemical storage and makeup, process gas supply, material handling, equipment decontamination, and maintenance systems would also be required.

The ceramic immobilization facility would be designed to ensure that surface facilities could withstand earthquakes, high winds, and floods. The fire protection systems of the plant would be in accordance with DOE orders and National Fire Protection Association Codes and Standards. The material would be handled to ensure criticality safety. The physical security, materials control and accountability, IAEA safeguards, and physical security system facilities would be consistent with protecting DOE-defined Category I and II type special nuclear materials.

Facility Operations. Operations at the ceramic immobilization facility would process both Pu metal and oxide. The Pu metal would be oxidized, added to the material received as Pu oxide, and the oxides dissolved in an electrochemical solution consisting of nitric acid and silver nitrates. Plutonyl nitrate solution formed from the dissolution process would be mixed with ceramic additives called precursors. After sampling and feed adjustment, the solution would be calcined in a rotary calciner and converted to oxide powder. The powder would be fed into an anvil powder compacting press, which would compact the oxide powder to form green ceramic pellets. The pellets would be sintered at 1,200 degrees Celsius (°C) (2,200 degrees Fahrenheit [°F]) for about 8 hours. The resultant pellets would be spheres, about 2.54 cm (1 in) in diameter, and would contain about 1 percent Pu by weight. The pellets would contain Pu dispersed throughout the sphere, with an exterior coating of durable non-Pu-bearing ceramic material, and would be shipped to the deep borehole site via SST. The material flow through the ceramic immobilization process is shown in Figure 2.4.3.2.1–2.

The ceramic immobilization facility could process Pu metal and PuO₂ feed in the amount of 25 kg/day (55 lb day). Operations would be based on 3 shifts per day, 7 days per week, 24 hours per day. Normal plant availability is considered to be 200 days per year. The oxide dissolution rate is about 1.1 kg/hour (h) (2.4 lb/h). About 126 l (33 gal) of 200 g Pu/l (1.6 lb/gal) plutonyl nitrate solution is produced each day. Annual utility consumptions for the ceramic immobilization facility are listed in Appendix C, along with the chemicals consumed during ceramic immobilization operations and the number of personnel required during ceramic immobilization operations.

The raw water requirement for the ceramic immobilization facility would be approximately 322 million l/yr (85 million gal/yr). The annual water balance diagram for the ceramic immobilization facility is shown in Appendix D.

Construction. Additional land area requirements during construction of the ceramic immobilization facility would be approximately 28 ha (70 acres) of land for construction activities, laydown, and temporary parking. The construction of the ceramic immobilization facility would require 5 years and have a peak annual employment of 1,000 construction workers. Materials and resources consumed and employment needs during facility construction are listed in Appendix C. The peak construction year is based on the construction schedule. Estimated total quantities of solid and liquid wastes generated from activities associated with construction of new facilities are shown in Appendix E. [Text deleted.] Solid wastes would be hauled offsite for disposal during the construction period.

Waste Management. The ceramic immobilization facility would have its own facilities to control emissions of criteria pollutants, toxic and hazardous air pollutants, and other gases emitted during operation and construction.

Facility waste management would also include handling and treatment operations for processing TRU, low-level, and mixed wastes, as well as industrial waste in aqueous, organic liquid, or solid forms generated from onsite operations. Waste management would be in accordance with DOE Order 5820.2A and RCRA. TRU waste generated from operations would be disposed of at WIPP (should DOE decide to operate WIPP for TRU disposal) in accordance with WIPP WAC (WIPP-DOE 069) and in accordance with decisions to be made as a result of the *Waste Isolation Pilot Plant Disposal Phase Supplemental EIS*. The waste management process flow diagram and annual quantities of wastes expected to be generated during ceramic immobilization operations are shown in Appendix E. The estimated air emissions from the ceramic immobilization processes are shown in Appendix F.

Transportation. Intrasilite transport of radiological materials at the ceramic immobilization facility would be limited to the transport of shipping containers of Pu metal and oxide into the processing facility and the shipping and handling of ceramic pellets containing Pu. Intersite transportation requirements exist for material coming into the ceramic immobilization facility from offsite and material being shipped from the ceramic immobilization facility to the deep borehole complex.

2.4.3.2.2 *Deep Borehole Complex—Immobilized Disposition Alternative*

Facility Description. The facilities required for disposal after immobilization are similar to those for direct disposition (Section 2.4.3.1), with minor exceptions in the receiving and storage facilities and an additional pellet-grout mixing facility and process waste management in the emplacing facilities. As explained in Section 2.4.3.1, subsurface facilities would consist of an array of four separate boreholes, with each deep borehole separated approximately 500 m (1,640 ft) from the next nearest hole. Each deep borehole would be about 4 km (2.5 mi) in depth. Figure 2.4.3.2.2–1 shows the cross-section of a typical deep borehole, in which the upper 2 km (1.25 mi) or more of depth would pass completely through the water table. The deepest 2 km (1.25 mi) would be drilled into crystalline basement rock that is isolated from the accessible environment.

The deep borehole complex would require approximately 2,041 ha (5,043 acres) and would include the same five groups of surface facilities with the subsurface borehole array as discussed in Section 2.4.3.1. The deep borehole site layout is shown in Figure 2.4.3.2.2–2.

The deep borehole facilities would be designed to ensure that surface facilities could withstand earthquakes, high winds, and floods. The fire protection systems of the site would be in accordance with DOE orders and National Fire Protection Association Codes and Standards. The physical security, materials control and accountability, IAEA safeguards, and physical security system facilities would be consistent with protecting DOE-defined Category I and II type special nuclear materials in the deep borehole complex above ground facilities. In addition, the material would be emplaced to ensure post-emplacement downhole criticality safety.

Facility Operations. The deep borehole complex would receive ceramic pellets of immobilized Pu from the ceramic immobilization facility. Material handling of the pellets would be accomplished at the borehole site, mixing ceramic pellets with grout before emplacement. No canisters would be required to emplace the ceramic pellets into the boreholes. This operation would be done without contamination risk or radiation hazard at the deep borehole site during normal operations. As in direct disposition, the containment structure located above the deep borehole entrance would contain any Pu releases if there were accidental breakage. The material flow through the deep borehole facility is shown in Figure 2.4.3.2.2–3.

The surface processing and emplacement/sealing facilities of the deep borehole complex would operate 5 days per week, 8 hours per day, 250 days per year. The drilling facility would operate 7 days per week, 24 hours per day in two 12-hour shifts with three drilling crews. The surge rate would be handled by introducing a second 8-hour shift in the surface processing and emplacement/sealing facilities and adding a second drilling rig and additional crew, if needed, in the drilling facility. Annual utility consumptions for the deep borehole operations are listed in Appendix C, along with the chemicals consumed and the number of personnel required during deep

borehole operations. The annual water balance diagram for the deep borehole facility is shown in Appendix D. The raw water requirement for the deep borehole facility would be 138 million l/yr (36 million gal/yr).

Construction. Additional land area requirements during construction of the deep borehole complex would be 6 ha (15 acres) for construction laydown, warehousing, and temporary parking. The construction of the deep borehole facility would require 3 years and have a peak annual employment of 810 construction workers. Materials and resources consumed and employment needs during facility construction are listed in Appendix C. The peak construction year is based on the construction schedule. Estimated total quantities of solid and liquid wastes generated from activities associated with construction of new facilities are shown in Appendix E. [Text deleted.] Solid wastes would be hauled offsite for disposal during the construction period.

Waste Management. The deep borehole complex would have its own facilities to control emissions of criteria pollutants, toxic and hazardous air pollutants, and other gases emitted during operation and construction. Facility waste management would also include handling and treatment operations for processing industrial waste in aqueous, organic liquid, or solid forms generated from the onsite deep borehole operations or from other site activities. Waste management would be in accordance with DOE Order 5820.2A and RCRA. The waste management process flow diagram is shown in Appendix E as are the annual quantities of wastes expected to be generated during deep borehole operations. The estimated air emissions from the deep borehole operations are shown in Appendix F.

Transportation. Intrasite transport of radiological materials at the deep borehole would be limited to transport and handling of ceramic pellets. Intersite transportation requirements for radioactive material being shipped from the offsite ceramic immobilization facility to the deep borehole complex are shown in Section 4.4 (Table 4.4.2.2-1).